Co-simulation modelling of a medium sized thermal vacuum facility for test feasibility studies

The European Space Agency

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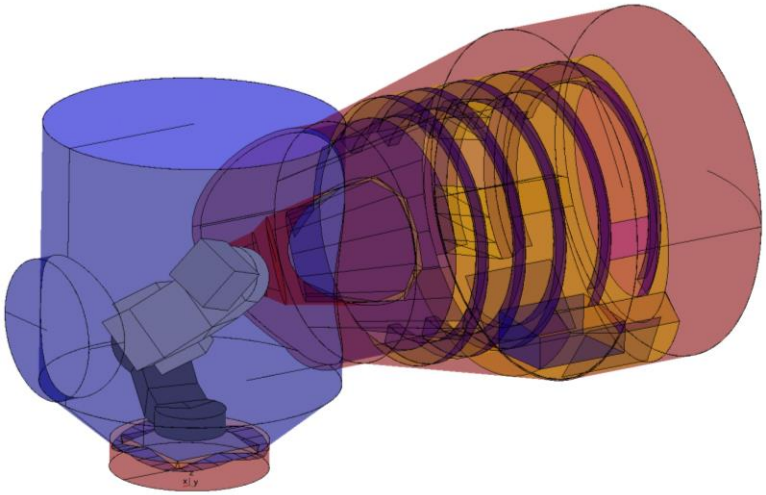
Background

- Thermal Modelling of TVAC chambers (LSS, PHENIX)
- Spacecraft thermal design:
  - Proba 3 / SMILE / JUICE
- STEP-TAS model conversions
- Development of thermal tools – post processor



Heat Flux Report

Results | Report Info

Group: SXI Radiator

Group: SXI Radiator

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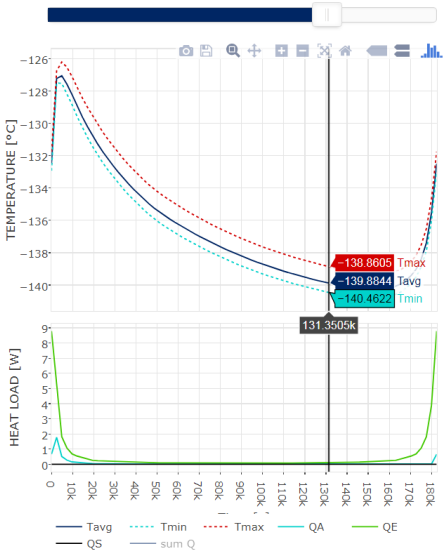
Heat from group	Conductive [W]	Radiative [W]	Total [W]
ENVIRONMENT		-4.0386e+0	-4.0386e+0
PLM Radiator mX		3.5435e-5	3.5435e-5
PM		2.6341e-1	2.6341e-1
SVM MLI		7.5918e-3	7.5918e-3
SVM Radiators		1.5412e-3	1.5412e-3
SXI FPA	3.2988e+0		3.2988e+0
SXI Radiator MLI	1.7698e-1	7.7041e-2	2.5402e-1
Solar Array		9.7598e-5	9.7598e-5
QA			7.3087e-3
QE			9.6728e-2
QS			1.8684e-2
Total [W]	3.4758e+0	-3.6888e+0	-9.0307e-2

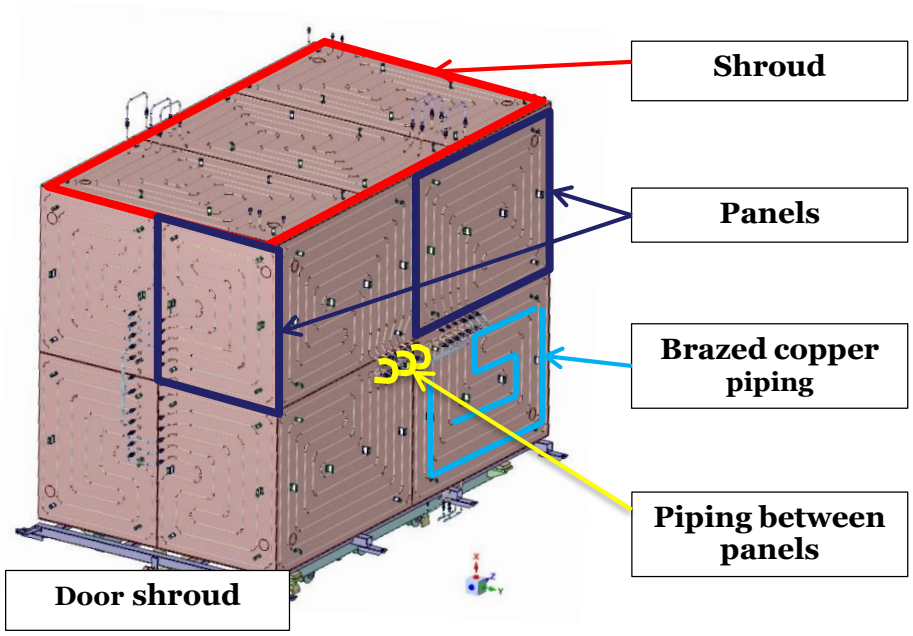
esa



Overview

- PHENIX Thermal Vacuum Facility
- Objectives
- Software selection
- ESATAN Model
  - Software description
  - Model description
  - Main heat path + convection
- EcosimPro Model
  - Software description
  - Model description
- Co-simulation
- User Interface
- Conclusions and model validation plan

PHENIX



Name	Volume	Length	Diameter	Min Temp.	Max Temp.	Thermal Channels	Sun Diameter
VTC 1.5	10 m^3	2.5 m	1.5 m	100 K	423 K	2	N/A
Phenix	160 m^3	10 m	4.5 m	100 K	373 K	6	N/A
LSS	2300 m^3	10 m	9.3 m	100 K	350 K	2	6 m

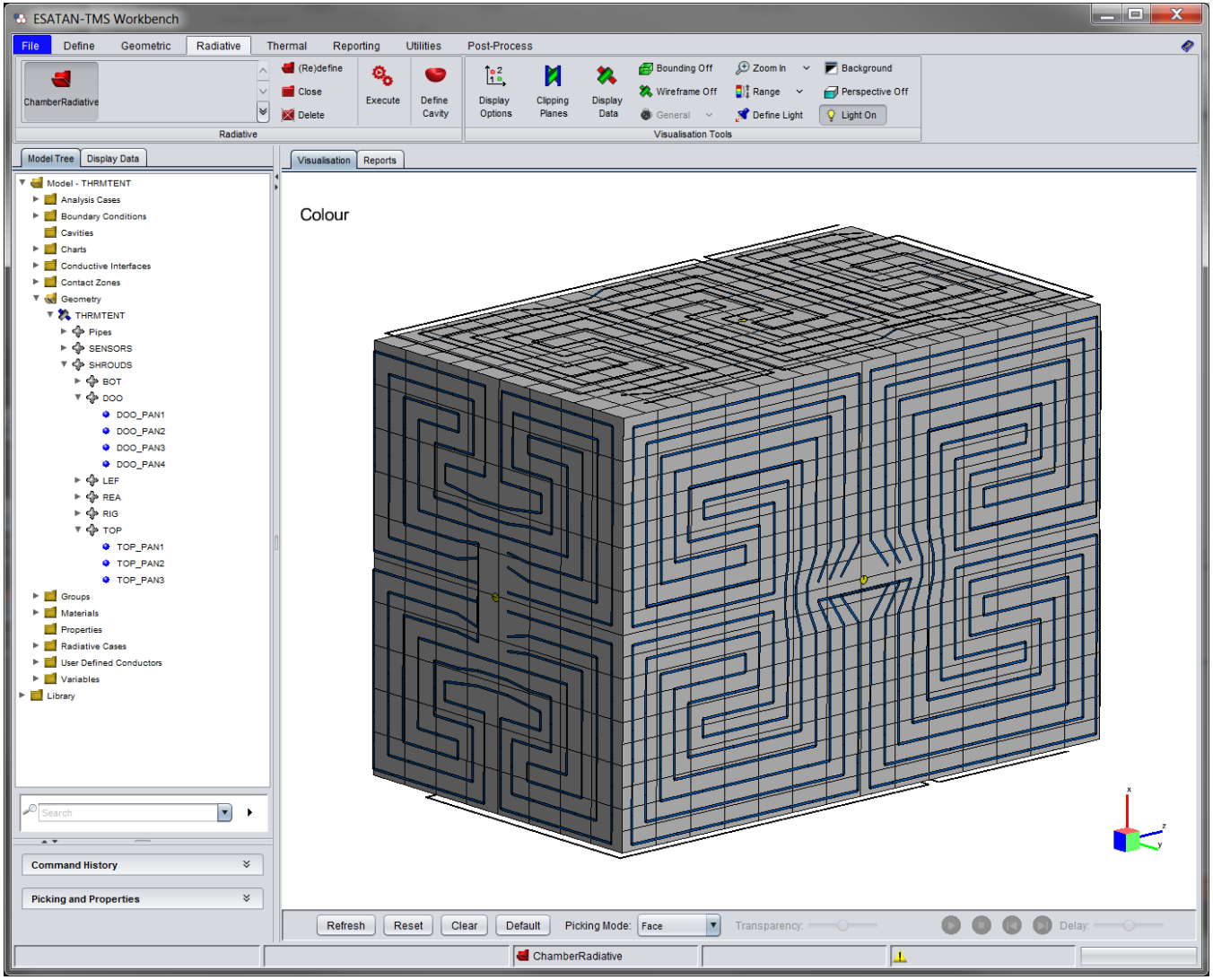
Objectives

1. Design a feasibility test with a given chamber blockage and dissipation, determine the heat loads on each shroud:
   - GN_2 = 600 W/shroud – max 2kW total
   - LN_2 = 60 kW total

2. Estimate the shroud temperature homogeneity (ΔT), to determine if it is acceptable for a given test.

3. Develop a tool for use by a thermal non-specialist.

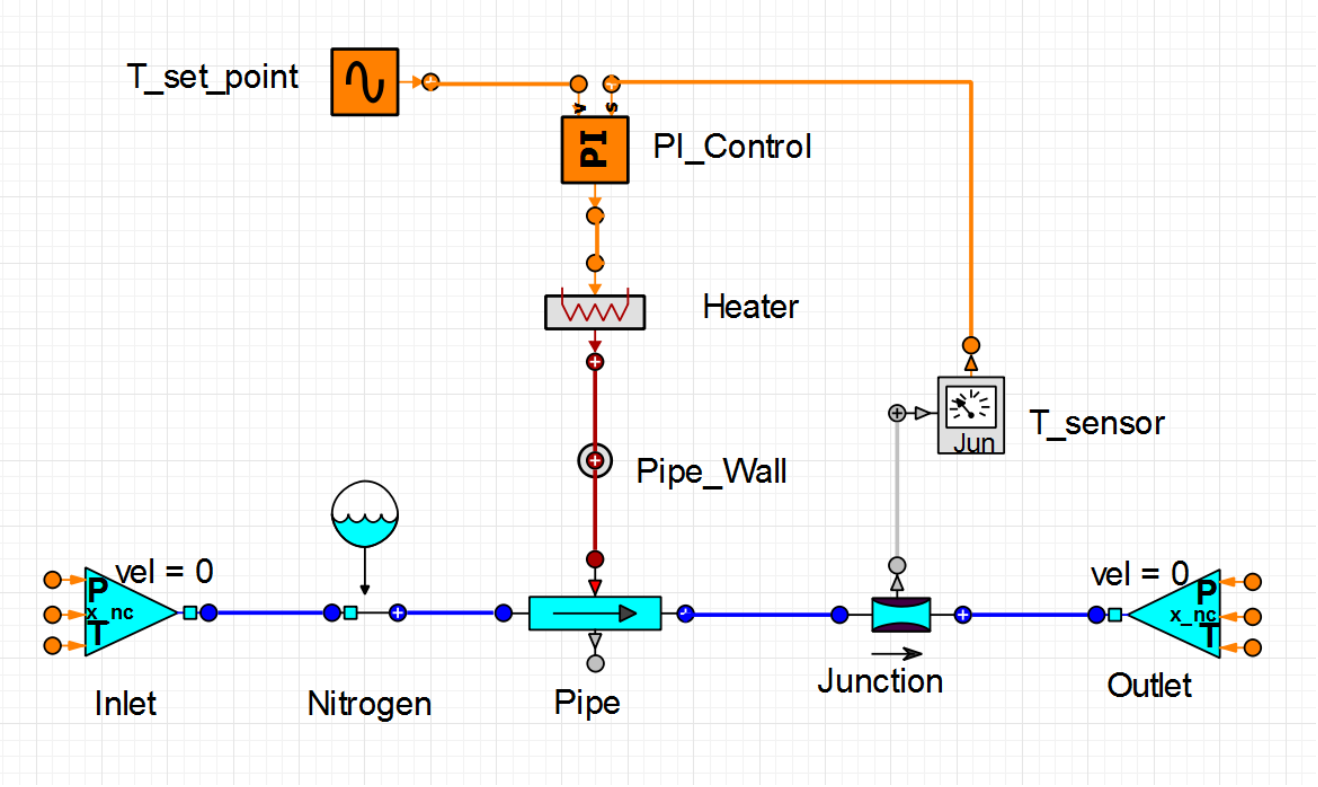
ESATAN-TMS


ESATAN-TMS Workbench
File
Define
Geometric
Radiative
Thermal
Reporting
Utilities
Post-Process
ChamberRadiative
(Re)define
Close
Delete
Execute
Define Cavity
Display Options
Clipping Planes
Display Data
Bounding Off
Wireframe Off
General
Zoom In
Range
Define Light
Background
Perspective Off
Light On
Radiative
Visualisation Tools
Model Tree
Display Data
Visualisation
Reports
Model - THRMTENT
Analysis Cases
Boundary Conditions
Cavities
Charts
Conductive Interfaces
Contact Zones
Geometry
THRMTENT
Pipes
SENSORS
SHROUDS
BOT
DOO
DOO_PAN1
DOO_PAN2
DOO_PAN3
DOO_PAN4
LEF
REA
RIG
TOP
TOP_PAN1
TOP_PAN2
TOP_PAN3
Groups
Materials
Properties
Radiative Cases
User Defined Conductors
Variables
Library
Search
Command History
Picking and Properties
Colour
Refresh
Reset
Clear
Default
Picking Mode:
Face
Transparency:
Delay:
ChamberRadiative

EcosimPro

Libraries:

- European Space Propulsion Simulation System (ESPSS)
- Co-simulation with ESATAN



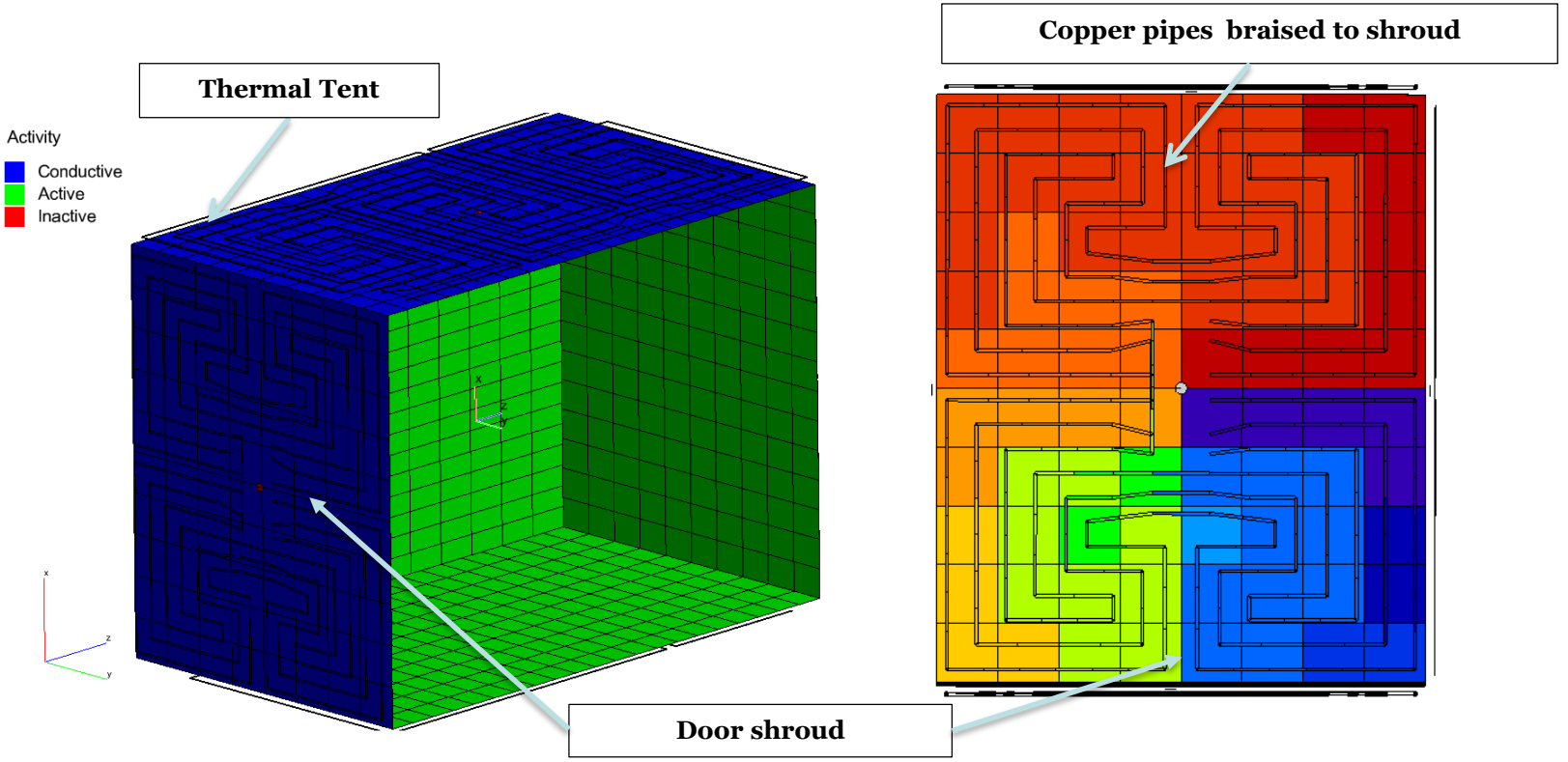
Why co-simulation?

- ESATAN-TMS
  - Option to include a user's spacecraft thermal model
  - Detailed temperature homogeneity map of each shroud

- EcosimPro
  - Allow component modelling of pipes, valves, inlets, outlets and control PI logic – easy diagnostics and variable access
  - Co-simulation library compatible with ESATAN-TMS
  - Modelling of mixing of cold and hot GN_2 lines
  - Option to integrate the tool into an Excel plug-in

ESATAN Model

- Radiative heat exchange inside the thermal tent
- Conductive heat exchanges between the pipe network and thermal tent walls
- Convective heat exchange from the fluid to pipe network



Main Heat Path

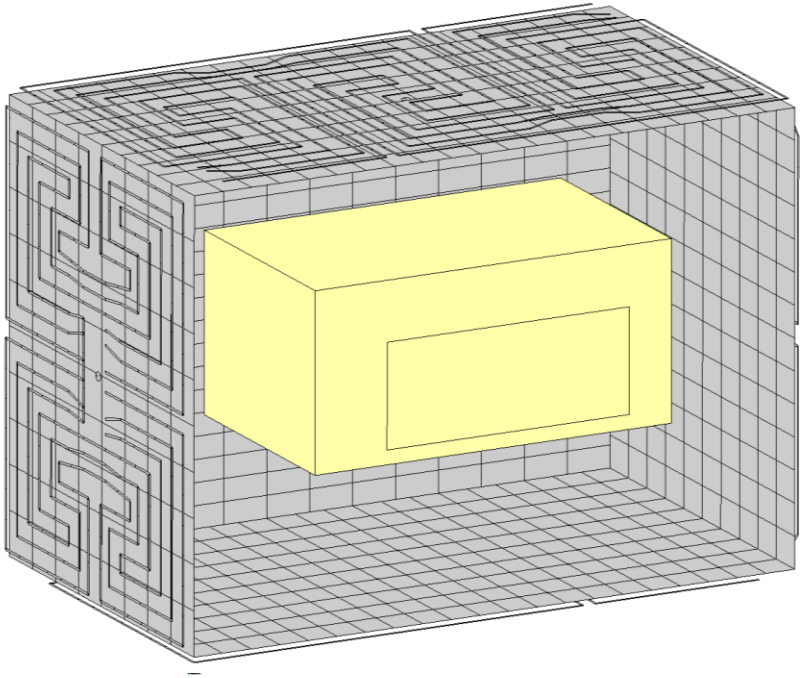
Key

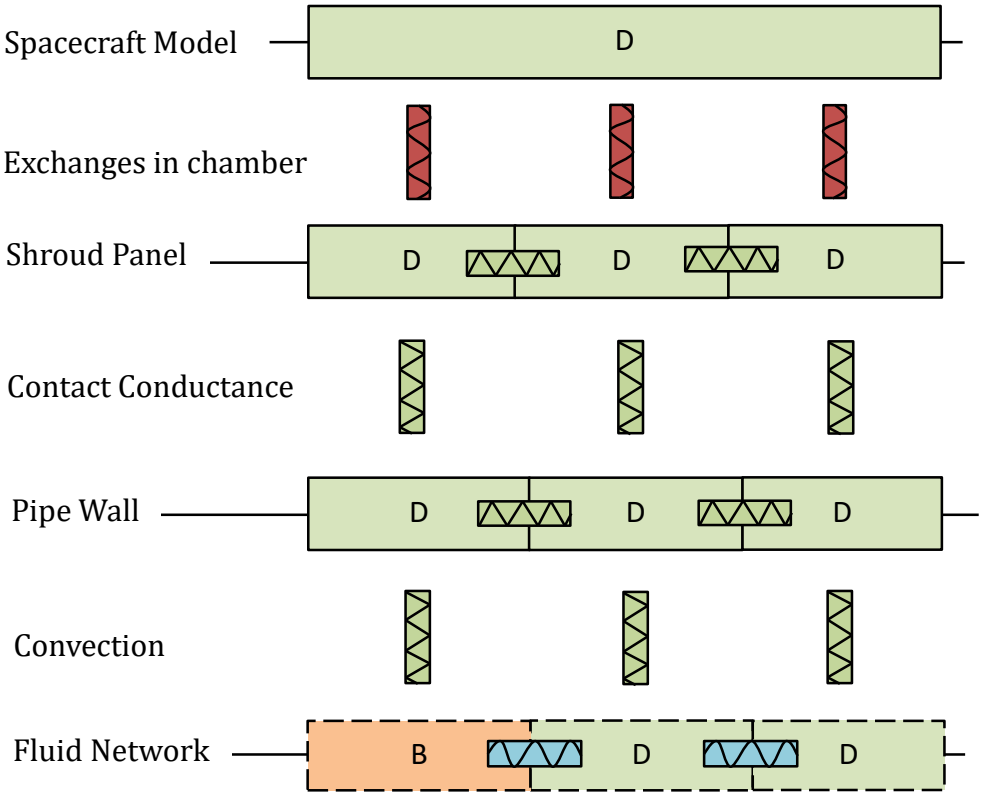
Nodes

- B — Boundary
- D — Diffusion
- D — Diffusion – fluid

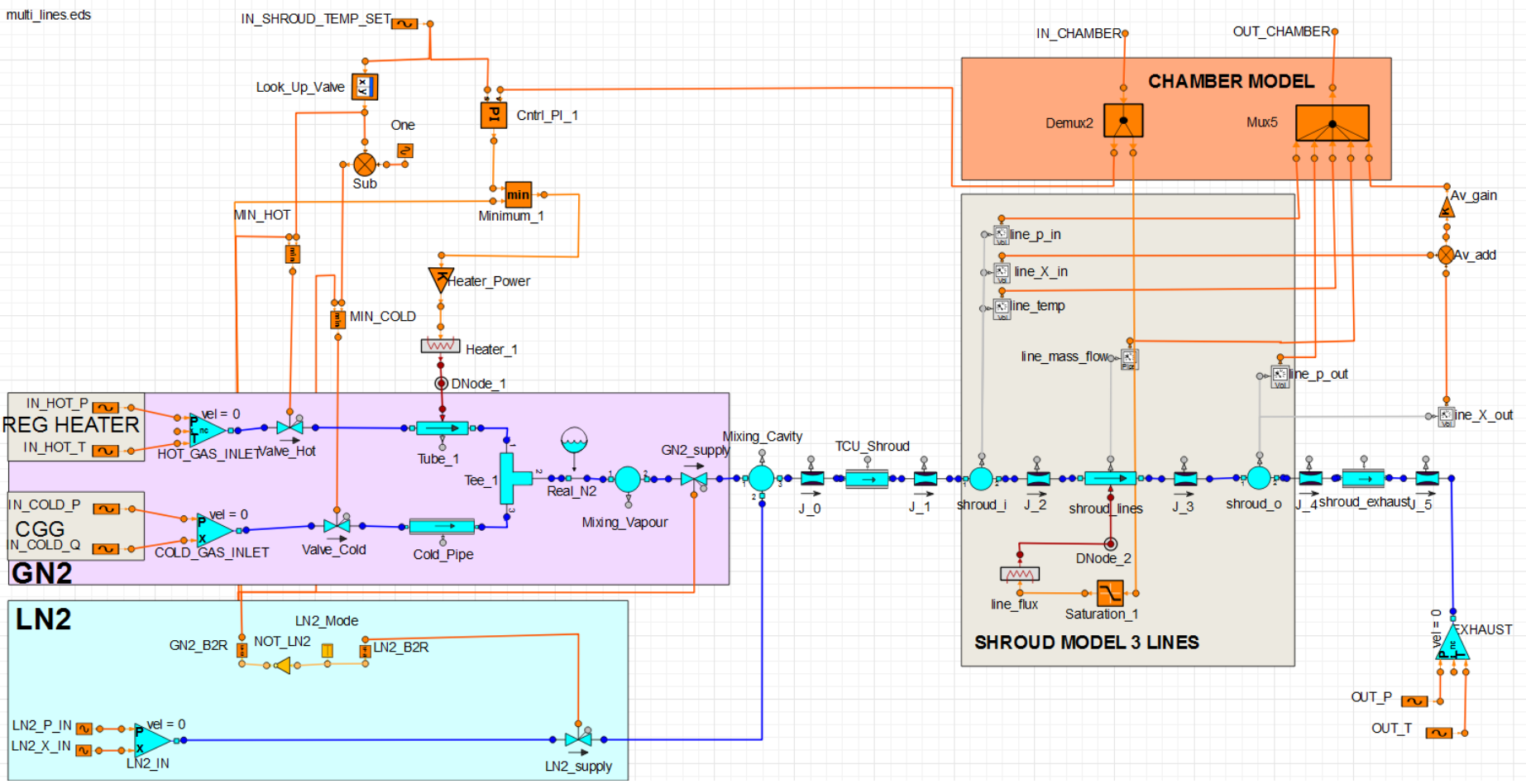
Conductors

- GR: Radiative
- GF: Fluid
- GL: Linear

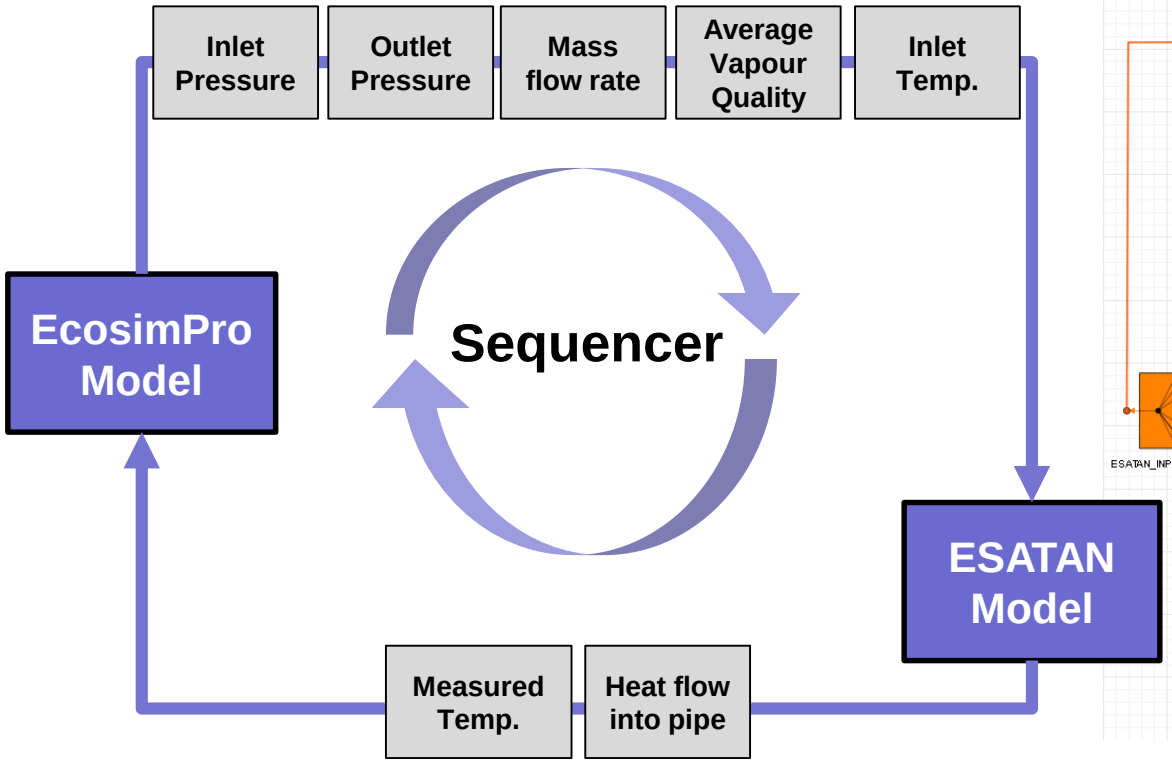


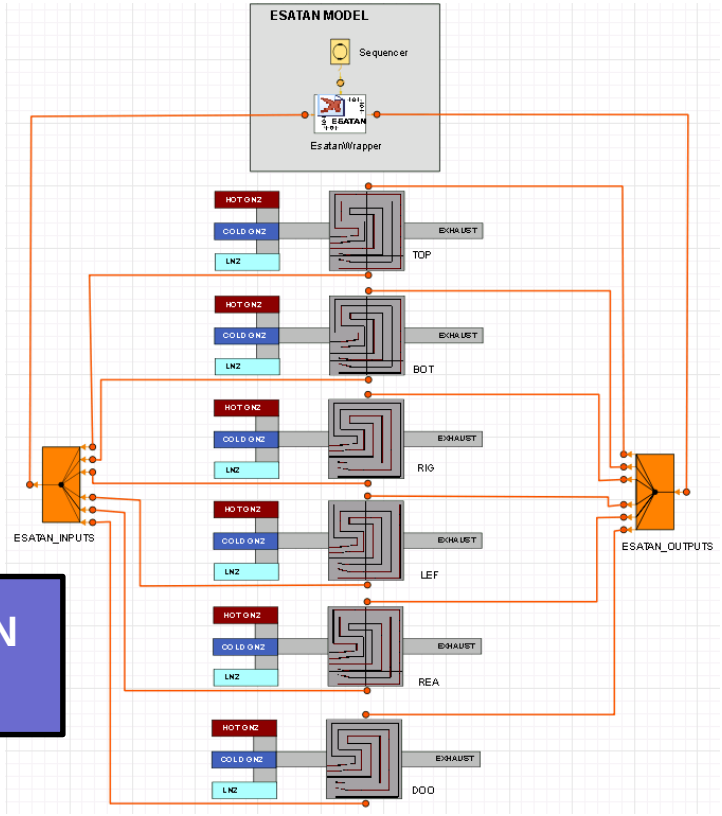


Single Shroud Model

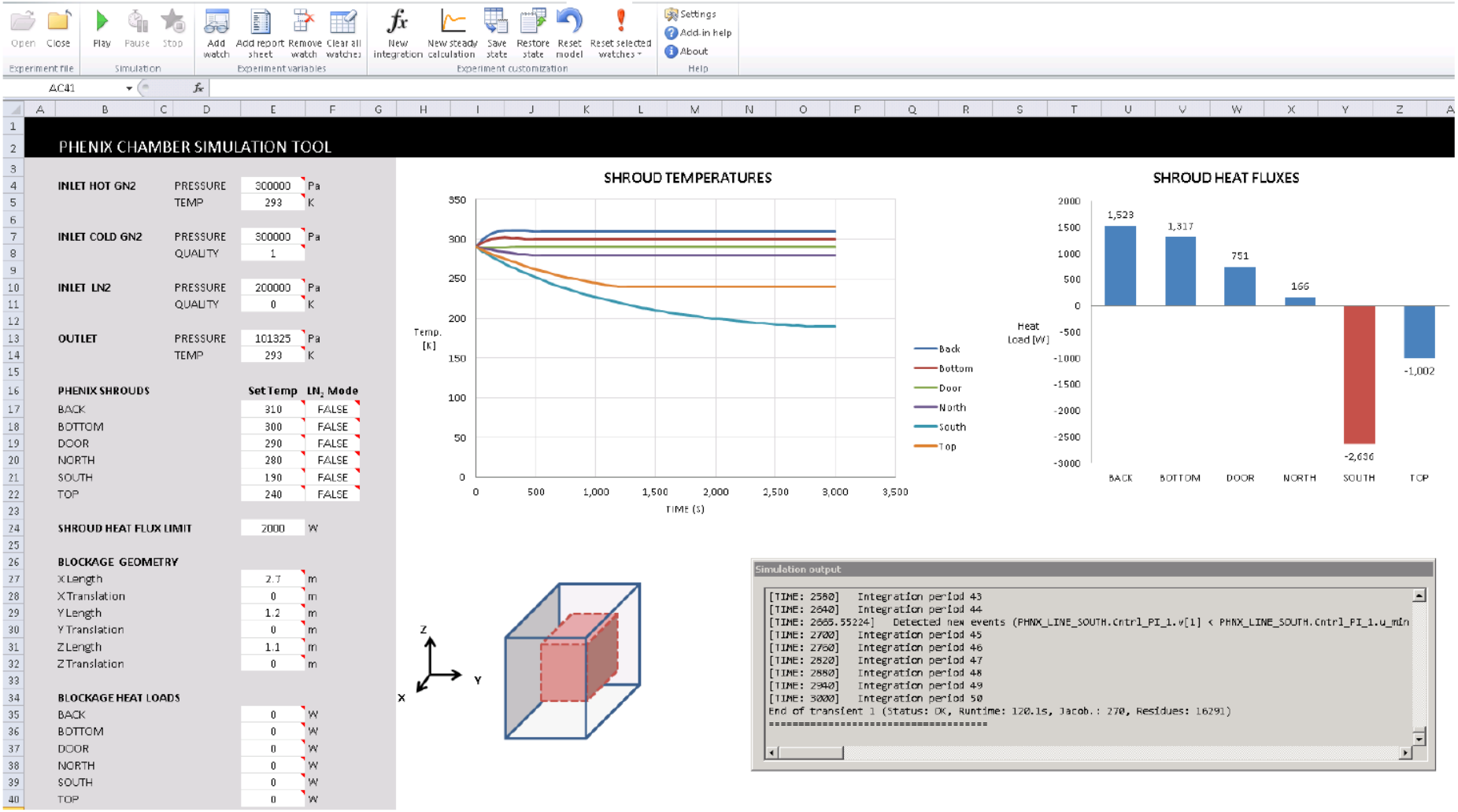


Co-simulation Connection





Excel interface



Model Validation

- Access to a range of thermocouple data on each shroud to estimate shroud temperature homogeneity
- Gaseous N_2 valve positions can be adjusted in the model
- Exercise to correlate steady state set-points of pipe temperatures.

References

[1] ESPSS European Space Propulsion System Simulation, EcosimPro Libraries User Manual, (VOLUME 1), 30-08-2015, Empresarios Agrupados, Madrid, Spain

[2] ESATAN-TMS Thermal Modelling Suite, ITP Engines, Leicester, UK, Online: https://www.esatan-tms.com/, Accessed: 28-07-2017

[3] ESTEC Test Centre Virtual Tour, ESA, Online: http://esamultimedia.esa.int/multimedia/ESTEC/virtualtour/, Accessed: 28-07-2017

[4] CoolProp – User-friendly interface around the full capabilities of NIST REFPROP, Online: http://www.coolprop.org/, Accessed: 28-07-2017